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ABSTRACT

This document consists of two parts. Part I outlines the general characteristics of science education research in the Federal Republic of Germany (and other German-speaking countries, such as Austria, the German Democratic Republic, and Switzerland). In addition, comparisons are made between research in these countries and research in other countries (including Great Britain and the United States). Areas addressed include: (1) applied research methodology; (2) teacher orientation; (3) Piaget as a reference for curricula; (4) preinstructional concepts; (5) analysis of key concepts in chemistry and physics; and (6) other research areas. Part II describes the characteristics noted in part I for four fields. These fields are: (1) research-based curriculum development; (2) national surveys and assessement studies; (3) evaluation projects; and (4) new theoretical paradigms. (JN)

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Karl Frey

Research in science education in the Federal Republic of Germany *

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Content

In Part I, I will outline the general characteristics of the research in science education in the Federal Republic of Germany. Part II describes these characteristics in four fields: 1) research-based curriculum development, 2) national survey and assessment studies, 3) evaluation projects, and 4) new theoretical paradigms.

Method

Neither section provides a complete, self-explanatory description of the situation in Germany, but rather elucidates by comparison with North America. In general I consider the Federal Republic of Germany, but in some places I also refer to the other German-speaking countries - Austria, the German Democratic Republic and Switzerland.

Researchers in Science Education

An indication of research capacity in the Federal Republic should first be provided. All teachers are required to have at least a Masters degree. The study courses demanded for the academic stream of secondary schools (Gymnasium) correspond - in U.S. terms - more to Ph.D. courses than to Masters courses. Professors of these student teachers form the main group of researchers in science education. They are organized in four societies, which also have members with an interest in the field, although they may not currently be actively involved in research. These societies include the Society for Chemistry and Physics Education, which has 330 members. The others are the section for life science education in the German Biological Society, with 150 members; the section chemistry education in the Society of German Chemists with 700 members and the section physics education in the German Society of Physical Scientists with 400 members. It would be fair to say that some 200 university faculty members and a few teachers are at present actively engaged in research. The rough estimate of 200 - 300 doctoral students working on their theses could also be added. These figures do not include teachers and professors writing essays and textbooks or engaged in developmental work.

In addition, the IPN at Kiel - the research Institute for Science Education, which operates at a national level and is financed jointly by federal and state authorities - has some 40 permanent academic posts and a group of research associates.

Part I: COMPARISONS

(1) In Germany we have always used a variety of research methods in science education. In the short history of our discipline, quantitative research techniques have not been the primary, dominating means of investigation. The following examples give some indication of the wide range of methods employed: writing the history of science education in schools from a particular perspective (Brüggemann 1967); analysis of the logical elements and their meaning as a scientific construct or term such as amount of substance in contrast to number, for example, or thermodynamic concepts such as ability to do work and entropy (Weninger 1981; Skotnicky, Weninger 1[illegible]; Falk, Herrmann 1977) as a platform for curriculum development; comparison of the conditions for producing knowledge in mathematics outside education and reproducing it in a scholarly context (Jahnke, Otte 1981); founding alternative conceptual structures for biology teaching (Kattmann/Isensee 1975) or the application of a theoretical term such as "alienation" in the post-marxist sense to science education in schools (Höhn 1980).

Phenomenological studies, however, are scarce - despite the fact that Edmund Husserl, who introduced the phenomenological method in his "Logische Untersuchungen" (1900 and 1901) was a German mathematician. This also applies to axiomatization. Wolze (1982) alone uses this procedure in his attempt to axiomatize the basis of an activity theory designed to integrate scientific knowledge, its development by scientists and its acquisition by learners in schools. And there is probably only one study which can be termed hermeneutic - Schuldt's study (1982) on the influence of the industrial, technological climate on science education in the thirties. Here the parallel with phenomenology is quite distinct. It was Wilhelm Dilthey - one of the last German philosophers to deal with the whole range of science and culture - who one

hundred years ago made the distinction between the exact sciences (Naturwissenschaften) and the human sciences (Geisteswissenschaften). Dilthey established a set of conditions and rules according to which human actions as reflected in documents can be scientifically elucidated and interpreted - such as in the codified curricula, for example. Dilthey called his method "hermeneutics" (Dilthey 1884/1977; Gadamer 1965; Herrmann 1978). Perhaps I can convey an impression of the hermeneutical approach by saying that compared with the required systematism of hermeneutics, Cremin's (1961) history of progressive education is written in too lively a style and from too many different perspectives, although it is related to this genre and bears some similarity to it. A hermeneutic analysis in its ideal form is based on explicit, normative statements but is not committed to one direction to the same extent as Schwab's Practical (1971 ff). In a way it is also conceptually more preconceived than Eisner's (1980) artistic approaches.

If we consider approaches first published in the United States, we see that symbolic interactionism (Mead 1934; Blumer 1969) enjoys greater popularity than any other concept as a kind of background awareness among general educationalists. But although tacit knowledge for many, it has not been explicitly reflected as a methodology in science education research. The same applies to ethnomethodology (Garfinkel 1967), which was not able to achieve any appreciable effect on research. However, two theories exist for which Glaser and Strauss' term "grounded theory" (1967) can be used. They have been developed in a similar manner to Flanders' (1982) "Simlog", with an iterative use of theoretic concepts and quantitative data. The first was elaborated by Jung (1982) and concerns the learning of Newtonian dynamics, while the second - elaborated by Todt (1984) - deals with the development of interests in science education.

Science education research in the Federal Republic of Germany is thus characterized by a plurality of methods which comprises more than simply a dichotomy of experimental and

naturalistic inquiry (Welch 1983) or scientific and artistic approaches (Eisner 1980). The variety is reflected in the distribution of research types in doctoral dissertations - which might be considered as an indicator of the scientific activities of a discipline.

	Austria	Federal Republic of	%	German Democratic Republic	%	Switzerland	United Kingdom	%
empirical investigations	3	21	27	79	25	2	44	50
conceptual studies	1	25	32	64	20	1	5	6
historical and comparative studies	1	5	6	13	4	-	18	20
development enterprises	-	12	16	46	15	-	4	5
analytical studies	-	10	13	33	10	-	17	19
theoretical reflections	2	4	5	20	6	-	-	-
other studies	-	1	1	63	20	-	-	-
Total %			100		100			100

Table 1: Distribution of research of theses of the German speaking countries in comparison with the United Kingdom (from Nentwig, Frey, Klopfer, Layton 1983)

Various factors contribute to the plurality. Most of the academics involved in science education took their doctorate or even obtained their tenure in biology, chemistry or physics - and followed no courses in empirical research technique in social science. In the schools of education in gen-

eral, methods of empirical psychology influenced the high standards of educational research, yet were not able to initiate a broad range of activities in this field. In the fifties and sixties, many German, Swiss and Austrian educationalists acquired in the course of their career a strict methodology in philosophy, history or theology including hermeneutics, phenomenology and exegesis. This period of academic education still affects methodologies today, or at least confirms the claim of a pluralism in method. In view of these facts, it is perhaps rather surprising that there are only two real hermeneutic and phenomenological studies in science education available - and the same applies to education in general. The historian, Herrmann (1978), ascertained that many of the German educationalists in the hermeneutic tradition substituted their personal or social convictions for hermeneutics and combined them with the idea of action research (e.g. Klafki 1982). Interesting new types of scientific activity grew out of this, but hermeneutics receded into a peripheral role. Perhaps the renaissance of traditional European methods can be expected to come from North America, where methodologists such as Cronbach (1983) have been trying to complement quantitative methods with aspects of Dilthey's "Geisteswissenschaft" and its methodological core, hermeneutics (Dilthey 1884 / 1974).

Pluralism does not, however, only offer advantages. In a relatively small scientific community such as science education, methods are in danger of not being treated with the necessary degree of precision, or of being treated simply as methods without attaining the level of methodologies, which involve a theory as well as a method or technique. On the other hand, several researchers are using advanced statistical research techniques. At the IPN, for example, we used and developed further Rasch's probabilistic model

years before it became popular in the United States.

The second problem concerns the lack of empirical data. Compared with some Anglo-Saxon countries, much less empirical data are available in the German-speaking countries, although an exception may be found in the German Democratic Republic in the area of achievement and cognitive processes (Lompscher 1968; Klix 1971). Quite intensive efforts to compensate for this lack of data can be observed at present in the Federal Republic of Germany (Hedewig, Staeck 1984). However, it is hardly likely that each researcher will be expected to produce empirical data - or even experimental or quasi-experimental designs.

(2) In the United States, some have attempted to focus research on the needs of science teachers. Therefore, empirical need assessments have been carried out (e.g. Yager 1978). No such activities are conducted in the Federal Republic of Germany. And no publications are available to compare with, for example, "What research says to teaching" published by NSTA. This may be regarded as a shortcoming if research in this area is to influence practice. At the IPN we have therefore discussed activities similar to the NSTA's series. On the other hand, one must bear in mind that teacher training and in-service education in working-groups, rather than written information, are the major influences on practice. This probably applies at least to the Federal Republic of Germany, where there is little inclination to read voluminous texts. We know from assessment of in-service training courses, from the teachers' perception of the practical value of their own professional education (Eigler 1983; Ronellenfitsch 1979), and from a national survey of in-service training (Bloch et al. 1983) that the needs which currently dominate all other areas are for assistance in classroom management, news of advanced research in biology, physics and chemistry, as well as the opportunity for talks with other science teachers. It would be short-sighted if the research questions only followed the teachers' immediate needs. But apart from

these considerations, one is justified in saying that research in science education in the FRG has not concentrated so much on the improvement of classroom behaviour of teachers as is the case in the United States, or to a certain extent in Great Britain and in the German Democratic Republic.

Looking at the doctoral dissertations again, we find a number of subjects which are emphasized by current research in science education. The following table, comparing the number of theses (1970-1980) in the United Kingdom and both parts of Germany, shows significant differences between the countries.

	Federal Republic of Germany	%	German Democratic Republic	%	United Kingdom	%
1) subject in general curriculum	8	6	31	5	1	1
2) aims and objectives	5	3	15	2	4	3
3) implications of science disciplines	20	14	70	11	7	4
4) curriculum studies	28	20	54	9	30	20
5) educational systems	3	1	12	2	19	13
6) didactic approaches	21	15	33	5	7	5
7) social ... etc. implications	8	6	38	6	3	2
8) teaching person	2	1	8	1	4	3
9) teaching methods	2	2	76	12	5	3
10) experiments	6	4	50	8	7	5
11) teaching-learning processes	16	11	41	7	17	11
12) media	5	4	60	10	2	1
13) effects of science education	13	9	114	19	35	23
14) history	4	3	8	1	9	6
15) special learner	-	-	4	1	-	-
Total %		100		100		100

Table 2: Distribution of research subjects between countries (from Hentwig, Frey, Klopfer, Layton 1983)

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IPN devi-es and conducts its own research planning. As IPN researchers are not simply engaged for the duration of a project, but hold permanent posts, a new phase of research planning for the institute as a whole is initiated every three years. In each of these phases, current projects are appraised and decisions made as to which should be modified or terminated. In addition, new working areas are introduced, a process which demonstrates particular features of organization. Initiatives and ideas emanate from public discussions and from a variety of other sources including administrators, teachers and scientists, as well as the IPN researchers. Input from outside the immediate research community is of vital importance. Consideration of the proposals again involves scientists from various disciplines and institutions, together with practitioners in education and well-known public figures from outside the field in question. The decision-making is therefore influenced by a combination of scientific and educational elements. This kind of research planning prevents an institution from becoming merely an instrument for solving immediate problems of the school system. The research instead covers the whole range of factors affecting students' learning processes. Two publications are available which describe the strategy of our research planning and school-related research products (Frey 1980; Frey, Riquarts 1984).

(3) A number of authors of curricula in the Anglo-Saxon world as well as in some developing countries, claim in their introductory chapters to follow the principles of Piaget's theories. In the German-speaking countries, however, Piaget is referred to less frequently. The reason is the following: constructs such as equilibrium, accommodation and adaptation of his theories on the development of knowledge through a transformation of action into logical systems are either too specific or too general to play a structuring function throughout a curriculum. And on the secondary level, a consistent application of his genetic epistemology would conflict with internationally acknowledged scientific theories and concepts of the world.

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Yet very limited, carefully specific implications have been drawn for teaching physics (Kubli 1979; 1983a; 1983b). W. Jung (1980) made a thorough analysis of Piaget's investigations and results, especially of their implications for physics teaching. He argued that for didactic purposes, Piaget's structural analysis should be completed by investigations paying closer attention to the specific contents of thought. Also the clinical interview has been developed further as a tool for viewing pupils' pre-instructional state vis-à-vis phenomena of the physical world and elaborating this through instruction (Frey, Pfundt, Jenelten-Allkofer 1982).

(4) In the Federal Republic of Germany, research into children's and adults' preinstructional concepts of scientific terms plays a similar role to this kind of research in North America. Stimulated by Piaget's study types, it became popular ten years ago. A series of empirical studies was subsequently conducted concerning science subject matter and intellectual developmental levels of learners (Seiler 1973; Klinger, Bormann 1978; Nachtigall 1979; Jenelten-Allkofer 1979; Gräber, Stork 1984). They are similar to the study type of Lawson, Renner 1974, 1975 or of Sayre, Ball 1975 and Klopfer 1981. But the inquiries soon developed beyond the original research question and method. This was chiefly due to two measures: supplementation of the clinical interview with standardized questionnaire elements and with genuine scientific foundation of the questions presented to the children and adults. In other words, it was investigated whether the interviewees understood the fundamental meaning of force, velocity or work in terms of Newtonian dynamics or whether they had alternative views (Jung, Wiesner, Engelhardt 1981; Klinger, Bormann 1978; Jung, Maichle 1978; Duit 1981; Bormann 1978). Piaget's interviews, in contrast, often do not discern between a scientific and an everday understanding of concepts. These studies were conducted within the framework of a European exchange of ideas - a somewhat rare occurrence - involving mainly research teams in Paris, Rome, Frankfurt and Kiel (cf. Viennot,1976;Vincentini-Missoni 1982; Fichera 1984). Closest attention was, of course, paid to the concepts in

physics used in studies throughout the world. These are - besides the concepts of classical mechanics - voltage and current in electric circuits (v. Rhöneck 1980; Schwedes, Schilling 1982) or light, colour and refraction (Heege, Schwaneberg 1982; Jung 1981) or space and time in special relativity (Machold 1982). In addition, the understanding of atoms and chemical reactions was investigated (Pfundt 1982). In biology no studies have followed this research method, but instead dozens of word association tests for biological concepts have been carried out (i.e Schaefer 1979).

Meanwhile, a new stage has been reached in the conceptualization of the field. Pre-instructional understanding of concepts in physics are not interpreted as misconceptions and juxtaposed with the scholarly formulation of the concept. Direct learning of the scientifically correct concept appears to be neither effective nor meaningful. Instead, the frame of the learners' and scientists' qualitative understanding has to be identified and elaborated. W. Jung (1983) founds this concept with reference to some aspects of theories of science, to the cognitive psychological network and to empirical studies in the field of geometrical optics and classical mechanics.

(5) One of the primary tasks of science education research in the Federal Republic of Germany is to analyze and, where required, clarify key concepts in scientific theories. Falk (1977) worked out the general meaning of the basic concepts of energy, entropy and thermodynamics, and used this as a basis for the development of a physics curriculum. Rang (1981) explicated the elements of heat, while several contributions have dealt with the "basic principle of quantum mechanics" (e.g. Weber, Wiesner 1981). Hammer (1982) and - for the past twenty years - Weninger (e.g. 1981) have focussed on chemical terms. The research aims mainly at ensuring that science education does not have to operate with concepts which rely on hidden assumptions, or which have been introduced via implausible operationalization, or which depend on vague, obtuse systems of reference (e.g. Fichera 1984 on special relativity). It appears that particularly intelligent students seek a full

understanding of scientific terms and become frustrated by purely nominal definitions or by operationalization where there is little evidence of its necessity. Analyzing and clarifying scientific terms is an old tradition among German physicists involved in teaching (cf. Ernst Mach; Friedrich Hund; Max Jammer). This tradition was supported by various schools of theory of science, including the reconstructionalists (e.g. Janich 1969, on the protophysics of time).

(6) The remaining areas of research in science education in the Federal Republic of Germany seem to me generally comparable with those in North America. They include research on text comprehension (Weltner, Hoffmann, Kanig 1982; Bleichroth 1983), for example, and on the effectiveness of illustrations in textbooks (Koch 1977; Staeck 1980). Further studies focus on the role of mathematical and intuitive thinking in solving physics problems (Euler 1981), or on the outcomes of teaching chemistry by letting students carry out their own experiments (Riekens 1982). There are also investigations into changes in students' interests (Weltner et al. 1980; Löwe 1982; Rolbitzki 1983) or knowledge acquisition (Gahl 1973; Löwe 1981; Lind 1982; Eschenhagen 1982, Entrich 1984), as well as into the amount of technical terms used in textbooks (Brämer, Clemens 1980). It would be quite accurate to say that research questions and methods in all these fields of science education in both parts of Germany are similar to those in North America. The only difference is in quantitative terms - in North America twice as much research is carried out as in Germany. (cf. Sipe, Farmer, 1982).

Part II: RESEARCH QUESTIONS AND METHODS IN SELECTED AREAS

(1) Research-based curriculum development

At present more than 70 different books, worksheet collections and curricula for science education are in circulation, due to the varying syllabi in the ten federal states and West Berlin, to the various approaches teachers prefer and to the dozen or so publishing companies active in this field. Yet none of these publications offers a solely theory-based approach. Some of the publications are updated versions of well-known textbooks with a long tradition, while others have resulted from long-term collaboration among teams of authors and editors in publishing companies. But none of them have been the product of planning and writing sessions such as the method used, for example, in producing Chem Study. A few curricula were stimulated by projects such as Nuffield or Science 5/13 in Great Britain, or on the ABC curricula in the United States, but the German counterparts could not afford comparable effort and expenditure (Tütken, Spreckelsen 1973; Schwedes 1976; Klewitz, Mitzkat 1977; Bloch 1978). Some of the German curriculum projects however, attain in relative terms an equivalent level of research carried out in the development process, or surpass the level attained by, for example, SCIS, BSCS, MACOS, HPP or CBA (CUNA 1981; Garlichs, Knab, Weinert 1983; Weninger, Pfundt, Dierks, Marcus 1982; IPN-Curriculum Physik 9/10 1975).

A number of the German projects conform to the international mainstream. They are concept, process or social oriented. They employ model methods, systems theory, information theory or take a genetic or historical approach (Schietzel 1960; Bleichroth 1983; Flörke/Flohr 1969; Schmidt 1972; Kattmann/Isensee 1975; Killermann 1974; Wagenschein et al 1973; Spreckelsen 1977; IPN - Curriculum Physics 9-10 (1975); Sexl 1979, 1980; Härtel 1982). After extensive theoretical reflection, half a dozen integrated science curricula have been developed (Frey, Blänsdorf 1974).

CUNA 1981). The integration of academic and vocational schools in grades 10 to 13 in North Rhine Westphalia, for example, stimulated a new type of curriculum, comprising scholarly chemistry or physics topics with a vocational training. An example of a combined national effort is AKTIF, an activity-based curriculum mainly for handicapped children (see Hameyer, Dudek, Strenge 1984). AKTIF is harmonized with the guidelines for science education in the eleven states of the Federal Republic of Germany. The curriculum, which aims eventually to reach some 20,000 teachers, was inspired by - and drew on - SAVI, a curriculum for the visually impaired (Lawrence Hall of Science, Berkeley). Each of these projects is characterized by elements of curriculum originality and various conceptual foundations. Some of them even aim to found the curriculum as a whole on an integral theoretical basis. Three may be mentioned here.

The first of these has been developed by Giel, Hiller, Krämer, Nestle and associates (1974/75), together with a large group of teachers, using Hiller's "Konstruktive Didaktik" as a background. This project created a new approach to primary education - including science education. The curriculum is entitled "Stücke zu einem mehrperspektivischen Unterricht" - MPU (roughly translated: components of multi-perspective instruction). It is based on the implications drawn from the theory of symbolic interactionism. The theoretical foundation reads as follows: If it is true that meaning depends on the nature of interaction among individuals and not on the products of interactions, the subject of teaching is thus not only knowledge in consolidated form, but also interaction, represented by the learning process itself. This must then also apply to the sciences. The process of becoming educated involves retracing the paths of consolidation. Science education is the reconstruction of a portion of the scientifically influenced world. The curriculum outlines four types of reconstruction: scientific, experiential, public/political

and scenic (naturalistic), to be applied in areas of activity previously agreed upon, e.g. traffic, production, communication - or in more concrete terms, a sparkling mineral water factory or television. For the teaching process, four levels of communication and four structural components are introduced. The mode of reconstruction is guided by knowledge concerning the growth of meaning - in the sense of interactionism. Hiller's very complex and sophisticated curriculum theory has only been applied in primary science education, not at the secondary level. It cannot be said to have had any great effect on the disciplines of biology, chemistry and physics.

The second project is a chemistry course of study for grades 8 to 13. The theory behind the project is to develop consistently the steps leading from an everyday perception to a scientific explanation of chemical processes. The curriculum structure assumes an inherent logic in the scientifically interpreted world, which can be revealed by observation and carefully introduced concepts (Weninger, Dierks 1974; Pfundt 1976).

For the third "project" this term is probably inappropriate, as by now it has developed a private school system of its own. It has its roots in Rudolf Steiner's philosophy of nature and education. Steiner shared Goethe's encompassing view of nature, embracing all phenomena in a religious whole (in a "Naturreligion"). At the beginning of this century he drew up examples for a holistic comprehension of nature. The distribution of "Waldorf-Schulen" and the involvement of dozens of scientifically educated people with Waldorf education led to a differentiation of Steiner's original ideas. Many of Steiner's writings have been incorporated into a viable program of instruction concerning primary science education (Lindenberg 1975; v. Mackensen 1976, 1979). The pupil is carefully guided towards constructive contact with nature. Children in kindergarten learn to feel the texture

of honey. Later the child is led in a strict, almost ritualistic way to handle harder materials such as iron. This process is completed towards the end of his education at around the age of 15 or 16. In the upper grades of most Waldorf schools, students receive vocational instruction related to a material such as wood or metal. Waldorf science education often engenders a certain antagonism in its students towards scholarly scientific knowledge, retaining for example Goethe's theory of colour or the phenomenological approach to forms of fire related to the four elements of antiquity. The majority of science educationalists in Germany regard the Waldorf approach as antiquated, and as far as modern physics is concerned, alienated from reality. Only a few are enthusiastic.

(2) National assessment studies

It is perhaps rather surprising that the Federal Republic of Germany is conducting no national surveys of student achievement of the kind familiar in the United States (e.g NAEP 1976/7; Hueftle, Rakow, Welch 1983). The centralized state-school system would, after all, provide an ideal context for the organization of state and nationwide assessment programs.

But the paradox within the German system is that this centralized state control makes monitoring of achievement less attractive, indeed even superfluous. The equality of learning opportunities and the maintenance of national standards are assured by a continuous policy of prophylactic measures. The major factor here is without doubt the preventive, programmatic curriculum system. This comprises elements such as standardized teacher training in state universities; a state-guided one and a half year induction phase for young teachers; guidelines in the form of a state syllabus for the production and authorization of textbooks and equipment. Another factor to be borne in mind is that teachers

throughout the Federal Republic are paid according to a uniform salary-scale - which by the way can easily compete with income attainable in industry. This system prevents such problems as high differences in achievement between schools.

Information on student achievement in the Federal Republic as a whole is therefore scarce, in fact practically non-existent. A nationwide survey apparatus and standardized tests are not available. Assessment of selected groups has been carried out, such as the 1971 study of student biology teachers (Eschenhagen, Schilke 1973) or the 1978 study of first-year university physics students (Krause, Reiners-Logothetidou 1981), but in general one can justifiably say that there are no national survey studies of the kind conducted in the United States and many other countries.

However, two new and somehow alternative study types have emerged. The first type focusses on classroom activities. A study scheduled for 1985 will analyze a representative random sample of classes in environmental education subjects such as biology and earth science (Eulefeld, Bolscho, Rost, Seybold 1984). This project will place less emphasis on a case-study approach than applied in Stake and Easley's study (1978).

The second study type analyzes the level of science education among adults and their former learning experiences in and outside school by means of standardized questionnaires. This type of study attempts to produce a comprehensive evaluation of educational outcomes and to relate these to the individual educational background.
It comprises - besides knowledge - such outcomes as science-based activities, attitudes, interests and manifest behaviour in relation to certain issues. Among the educational resources the adults listed in their curriculum vitae were the following: type of school, amount and quality of teaching in selected areas, areas, stimulating factors outside school and time elapsed since end of schooling.

One of these studies dealt with physics education, especially with knowledge, attitudes and behaviour in conjunction with energy and electricity (Häußler, Hoffmann, Rost 1985), the other with ecology (Langeheine, Lehmann 1984). Both studies were conducted with 20 to 40 year-old adults randomly selected. Preliminary results give some interesting insights into long-term effects of different educational measures.

(3) Evaluation studies

In North America a quantitative evaluation is usually required for curriculum projects. This is, however, not a part of German funding policy. Thus the Federal Republic does not provide sufficient primary data which would allow secondary analyses to be made, such as the Berman/McLaughlin (1977) study on curriculum implementation. On the other hand, it goes without saying that evaluation studies have considered such internationally common research issues such as the homogeinity of the learning group, class size, experimental work or teaching methods as factors affecting students' achievements (e.g. Weltner 1969; Wiebel, Sprockelsen 1977; Mikelskis 1980) or the way in which teachers convert written curriculum material into active classroom material (Duit, Riquarts, Westphal 1976; Mühlhausen 1983). The work carried out in this area in the last 15 years is on the whole similar to that carried out in Australia, England and other countries. The number of investigations conducted is significantly lower than in the United States and in the German Democratic Republic, yet higher than in other European countries. Some of the reasons for this situation have already been discussed in Part I. In this presentation of research methodologies in the Federal Republic of Germany, two recent evaluation approaches are worthy of mention:

(a) A specific type of evaluation activity was brought to developmental work in the late sixties - "multiperspective documentation" of project procedure. An activity of this kind provides a narrative description of scientific steps, contexts, problems and breakthroughs. Quotations and photo-

graphs are often added. The acceptance and use of this new type of scientific record-keeping can be attributed to several factors:
1) popularized knowledge about restrictiveness in quantitative modelling, 2) the application of action research along the lines of the philosopher Leon Brunswick and the psychologist Kurt-Lewin (e.g. Fuchs 1971; Haag et al. 1972) and 3) the substitution of Dilthey's "Geisteswissenschaft" (committed to hermeneutics) by the political intentions of the scientists (Herrmann 1978).

W. Klafki's report on his Marburger Grundschulprojekt (1982) is a typical research report of this kind. Klafki and his associates investigated possibilities and contextual factors of curriculum innovation relying on action research methodology. Similar reports have been published by Diederich and Wulf (1979), Benner and Ramseger (1977), Bielefelder Lehrergruppe (1979), Maurer (1978) and by Hameyer (1978) in the form of an empirically guided comparison of case-studies supplemented by interview data. This kind of work provides many insights into learning, motivation, moods, problems and highlights of individual students or small groups. The specifics are situational, yet the additional information is general enough to allow for similar experience in other classes. The modules retain the intention of being examples inviting modification and variation, but do not offer statements based on generalizations. This type of research is similar to the projects carried out in the last ten years at the French national institute for educational research (Host 1978, Giordan 1978, 1980). It also shows some aspects of what is internationally called ethnomethodology (Garfinkel 1967), yet quantification is not principally excluded (e.g. in Diederich, Wulf 1979).

If one reflects whether multiperspective documentation bears more resemblance to a method distinct from subject and object in the cartesian sense, or to a reflected interpretation of that which can be observed without a specific hypothesis, one must conclude that the latter is true. Multiperspective documentation is not founded in a non-contradictory context of discovery. And no multiperspective documentalist would

try to establish anything resembling a set of nomological hypotheses. The guiding principles of documentation issue from a personal sensitivity towards educational processes, enriched by various theories from the social sciences.

(b) An exciting new approach has been developed by Barbara Schenk (1984). It could be summarized as an attempt at a holistic evaluation of learning outcomes. As Schenk developed both a series of founding arguments and an example of procedure, we have here a rare example of a true methodology. The foundation is based on assumptions concerning on the one hand the delineation of scientific systematization facing the learner's potential, open-ended development processes, and on the other a concept of what scientific knowledge can be. One example has been developed for mechanics in grades 11 to 13, and a further example dealing with electric current is in preparation.

In concrete terms the evaluation is based on three frames of reference:

a) the learning process actually experienced, documented by both the future educator's observation and the student's own interpretation;

b) an interview technique comprised of standardized questions and an extended clinical interview including stimuli to raise unusual areas of knowledge;

c) extensive knowledge of the subject matter.

The latter point is probably the crucial element of Schenk's evaluation approach when applied in practice. Over the years, school physics has stagnated into a very specific and restricted discipline, hardly comparable with the science of physics in laboratories (Westphal 1980). Schenk's holistic evaluation approach therefore requires a higher degree of competence in physics and individual learning processes than is usually common among physics teachers, although this should prove no obstacle to using some elements of this approach in future for classroom evaluations, and more especially in oral examinations taken by science students.

(4) Two attempts to ground new approaches for science education

Earlier I mentioned new curricular structures, such as those based on an enlarged interpretation of thermodynamics (Falk 1977), information theory (Sexl 1979), phenomenological chemistry (Weninger, Dierks 1974) or cybernetic biology (Bayrhuber, Schaefer 1978). They have all been successfully implemented - or have at least demonstrated their potential. The two following attempts are still at an early stage of development, but in terms of their theory they are most promising - and above all, inspiring.

(a) The activity theory:

Under the general heading of activity theory, a fundamental attempt is being made to establish a comprehensive theory for science education. The theory is comprehensive insofar as it embraces educational as well as scientific elements in an integral theoretical concept. Using the same theoretical instruments it attempts to describe generation and transformation of knowledge. The core of the theory can be described as follows: both the subject - object relationship and the subject - subject relationship develop concurrently with the ideational and material activity. During this process the activity generates ideational states (structures) which in turn essentially determine the possibilities for regulating the activity.
Activity theories were first developed in the area of psychology, and these are still the most developed theories of their kind. These theories in psychology, however, comprise only in part an activity theory for education.

The object of education theory is the system comprised of learning activity and instruction activity, and the regulation of their development. The object of learning activity is not scientific laws alone, but also methods of research and the development of theories, methods and apparatus in the

scientific community - concurrent with the interaction of the latter and with the activity of society as a whole. Educational theory must, therefore, also encompass scientific activity. A particular problem is presented by the methodical and historical reconstruction of knowledge in such a way that the learning process can function in accordance with educational theory.

Apart from developing a general activity theory for science education, the projects are also concerned with the concrete reconstruction of elementary principles (e.g. principle of interaction, principle of retarded propagation of action, experimental methods, methods of concept introduction, Wolze 1982), as well as the reconstruction of theories in physics by applying these principles.

(b) The search for a new curricular structure, based on the concept of self-organization:

A number of researchers are investigating the possibilities of grounding the curricular structures in science education with the concept of "self-organization of matter". The principles of their thinking read as follows:
The concept "self-organization" sets an alternative to the entropic view of irreversible corrosion by exploring the features of recent developments in science. The important characteristic of these developments is the realization of self-organization as a key principle within natural processes. Research in this area focusses on open systems far from the equilibrium state, observes and analyses these systems when they pass through an instability threshold and establish a new structure. The principle recognizes evolution (the

growth of complexity and singularity) on all levels, be it the ascent of man, the heating of liquid layers or cognitive development. Thus the principle constitutes a deeper understanding of nature's evolutionary potential by realizing the processual character of natural phenomena. Science and science education, boiled down to equilibrium-oriented structures and to reduced, internal logic, are limited when faced with the diversity and richness of nature. Understanding the dynamic interplay between stability and instability (organized structures arising out of disordered states) provides an integrative tool for teaching science, establishes a bridge for openness towards problems in the ecology discussion and in the social sciences and, moreover, equips us with a broader perspective for our future history. Bloch (1983) is founding these ideas not only with authors such as Glansdorf, Prigonine 1971; Maturana, Varela 1979; Jantsch 1979, but also with Piaget 1981, as well as principles of social philosophy.

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